National Aeronautics and
Space Administration

Langley Research Center
Hampton, VA 23681-2199

The NASA SCI Files™
The Case of the
Powerful Pulleys

**A Lesson Guide with Activities in
Mathematics, Science, and Technology**

Please Note: Our name has changed! The NASA "Why" Files is now the NASA
SCIence Files™ and is also known as the NASA SCI Files™.

www.swe.org

www.buschgardens.com/buschgardens/va/index.html

www.cnu.edu
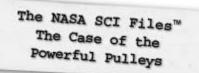
www.epals.com

www.sbo.hampton.k12.va.us

http://quest.arc.nasa.gov

NEC
NEC Foundation of America

www.nec.com

**The NASA SCI Files™
The Case of the
Powerful Pulleys**

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Program Overview

Accidents happen and Jacob has broken his foot. He is eager to get back into the tree house and join his friends, but the cast on his foot prevents him from climbing the ladder. The tree house detectives decide that devising a plan to get Jacob safely into the tree house will be their next case, and so begins *The Case of the Powerful Pulleys.*

As the tree house detectives research ways to get Jacob safely into the tree house, they visit Dr. D to learn about work, force, and energy. They decide that it is going to take a lot of energy to do the work needed to lift Jacob up to the tree house! There must be an easier way.

Dr. Textbook introduces the tree house detectives to the world of simple machines. Now they think they are getting somewhere. Dr D invites them to visit him at a circus to learn more about simple machines. At the circus, they think they have solved the problem. However, the tree house detectives know that they need to do a lot more research before they jump to any conclusions.

The tree house detectives set off to visit NASA engineers at NASA Langley Research Center and NASA Dryden Flight Center. Bianca is excited to learn more about engineers because she is preparing a report for Career Day. The Society of Women Engineers (SWE) helps the NASA SCI Files™ Kids Club in Raleigh, North Carolina provide valuable information about pulleys to the tree house detectives. With that information and after a trip to Legoland® , they think they are ready to solve the problem.

Come join the tree house detectives as they learn about simple machines, force, energy, work, and the world of engineering to discover that "pulling" Jacob up into the tree house is not as "simple" as they thought.

National Science Standards (Grades K – 4)

Standard	Segment			
	1	**2**	**3**	**4**
Unifying Concepts and Processes				
Systems, orders, and organization	✗	✗	✗	✗
Evidence, models, and explanations	✗	✗	✗	✗
Change, constancy, and measurement	✗	✗	✗	✗
Evolution and equilibrium	✗	✗	✗	✗
Science and Inquiry (Content Standard A)				
Abilities necessary to do scientific inquiry	✗	✗	✗	✗
Understanding about scientific inquiry	✗	✗	✗	✗
Physical Science (Content Standard B)				
Properties of objects and materials	✗	✗	✗	✗
Position and motion of objects	✗	✗	✗	✗
Life Science (Content Standard C)				
Characteristics of organisms			✗	
Organisms and their environments			✗	
Science and Technology (Content Standard E)				
Abilities of technological design	✗	✗	✗	✗
Understanding about science and technology	✗	✗	✗	✗
Science in Personal and Social Perspective (Content Standard F)				
Personal health			✗	✗
Science and technology in local challenges	✗	✗	✗	✗
History and Nature of Science (Content Standard G)				
Science as a human endeavor	✗	✗	✗	✗

National Science Standards (Grades 5 – 8)

Standard	Segment			
	1	**2**	**3**	**4**
Unifying Concepts and Processes				
Systems, order, and organization	✕	✕	✕	✕
Evidence, models, and explanations	✕	✕	✕	✕
Change, constancy, and measurement	✕		✕	✕
Evolution and equilibrium	✕			
Science as Inquiry (Content Standard A)				
Abilities necessary to do scientific inquiry	✕	✕	✕	✕
Understanding about scientific inquiry	✕	✕	✕	✕
Physical Science (Content Standard B)				
Motion and forces	✕	✕	✕	✕
Transfer of energy	✕	✕	✕	✕
Science and Technology (Content Standard E)				
Abilities of technological design	✕	✕	✕	✕
Understanding about science and technology	✕	✕	✕	✕
Science in Personal and Social Perspectives (Content Standard F)				
Personal health			✕	✕
Risks and benefits			✕	✕
Science and technology in society	✕	✕	✕	✕
History and Nature of Science (Content Standard G)				
Science as a human endeavor	✕	✕	✕	✕
Nature of science	✕	✕	✕	✕
History of Science		✕		

National Mathematics Standards (Grades 3 – 5)

Standard	Segment			
	1	**2**	**3**	**4**
Number and Operations				
Understand numbers, ways of representing numbers, relationships among numbers, and number systems.	✗	✗	✗	✗
Understand meanings of operations and how they relate to one another.	✗	✗	✗	✗
Compute fluently and make reasonable estimates.	✗	✗	✗	✗
Algebra				
Understand patterns, relations, and functions.			✗	
Represent and analyze mathematical situations and structures using algebraic symbols.	✗	✗	✗	✗
Use mathematical models to represent and understand quantitative relationships.			✗	
Analyze change in various contexts.			✗	
Measurement				
Understand measurable attributes of objects and the units, systems, and processes of measurement.	✗	✗	✗	✗
Apply appropriate techniques, tools, and formulas to determine measurements.	✗	✗	✗	✗
Data Analysis and Probability				
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.			✗	
Develop and evaluate inferences and predictions that are based on data.			✗	
Problem Solving				
Build new mathematical knowledge through problem solving.	✗	✗	✗	✗
Solve problems that arise in mathematics and in other contexts.	✗	✗	✗	✗
Apply and adapt a variety of appropriate strategies to solve problems.	✗	✗	✗	✗
Monitor and reflect on the process of mathematical problem solving.	✗	✗	✗	✗
Communication				
Organize and consolidate mathematical thinking through communication.		✗		
Communicate mathematical thinking coherently and clearly to peers, teachers, and others.		✗		
Connections				
Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.	✗	✗	✗	✗

National Technology Standards (ITEA Standards for Technology Literacy, Grades 3 – 5)

Standard	Segment 1	Segment 2	Segment 3	Segment 4
Nature of Technology				
Standard 1: Students will develop an understanding of the characteristics and scope of technology.	✗	✗	✗	✗
Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.	✗	✗	✗	✗
Technology and Society				
Standard 6: Students will develop an understanding of the role of society in the development and use of technology.	✗	✗	✗	✗
Standard 7: Students will develop an understanding of the influence of technology on history.		✗		
Design				
Standard 8: Students will develop an understanding of the attributes of design.	✗	✗	✗	✗
Standard 9: Students will develop an understanding of engineering design.	✗	✗	✗	✗
Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.	✗	✗	✗	✗
Abilities for a Technological World				
Standard 11: Students will develop the abilities to apply the design process.	✗	✗	✗	✗
Standard 12: Students will develop abilities to use and maintain technological products and systems.	✗	✗	✗	✗
Standard 13: Students will develop abilities to assess the impact of products and systems.	✗	✗	✗	✗
The Designed World				
Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.	✗	✗	✗	✗
Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.	✗	✗	✗	✗
Standard 20: Students will develop an understanding of and be able to select and use construction technology.			✗	✗

National Technology Standards (ISTE National Educational Technology Standards, Grades 3 – 5)

Standard	Segment			
	1	2	3	4
Basic Operations and Concepts				
Use Keyboards and other common input and output devices efficiently and effectively.	✗	✗	✗	✗
Discuss common uses of technology in daily life and the advantages and disadvantages those uses provide.	✗	✗	✗	✗
Technology Productivity Tools				
Use general purpose productivity tools and peripherals to support personal productivity, remediate skill deficits, and facilitate learning throughout the curriculum.	✗	✗	✗	✗
Use technology tools for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.	✗	✗	✗	✗
Technology Communication Tools				
Use technology tools for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.	✗	✗	✗	✗
Use telecommunication efficiently and effectively to access remote information, communicate with others in support of direct and independent learning, and pursue personal interests.	✗	✗	✗	✗
Use telecommunication and online resources to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.	✗	✗	✗	✗
Technology Research Tools				
Use telecommunication and online resources to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.	✗	✗	✗	✗
Use technology resources for problem solving, self-directed learning, and extended learning activities.	✗	✗	✗	✗
Determine when technology is useful and select the appropriate tools and technology resources to address a variety of tasks and problems.	✗	✗	✗	✗
Technology Problem-Solving and Decision-Making Tools				
Use technology resources for problem solving, self-directed learning, and extended learning activities.	✗	✗	✗	✗
Determine when technology is useful and select the appropriate tools and technology resources to address a variety of tasks and problems.	✗	✗	✗	✗

Segment 1

Jacob has broken his foot and is eager to rejoin his friends in the tree house. The tree house detectives decide that devising a plan to get Jacob safely into the tree house will be their next case and quickly begin to research the best way to lift him. Bianca decides that this case will also be a great opportunity for her to learn more about women engineers for her career day presentation. The tree house detectives begin their investigation with Dr. D, who helps them learn about energy, force, motion, and doing work. Deciding that they have the "energy" and are willing to do the "work," the tree house detectives contemplate building an elevator. However, after visiting Otis Elevator, they realize building one is too complicated even for the tree house detectives. On the way back to the tree house, they see a ramp and determine that must be the solution. They contact a friend who is in a wheelchair to learn more about ramps and how they help people with disabilities gain access to places.

Objectives

The students will
- understand the concepts of inertia.
- understand how the amount of force changes with the use of various simple machines.
- distinguish between potential and kinetic energy.
- understand the concept of gravity.
- use formulas to calculate work.
- learn that the Sun is the source of all energy for food chains.
- use a 12:1 ratio to construct ramps of different sizes.
- investigate various engineering careers.

Vocabulary

energy – ability to do work

force – push or pull that gives energy to an object, causing it to start moving, stop moving, or change its motion

friction – force that opposes the motion of an object

gravity – the mutual force of attraction between objects

inclined plane – slanted surface used to raise an object

inertia – tendency of objects to remain in motion or stay at rest unless acted upon by an unbalanced force

kinetic energy – energy that a moving object has due to its motion; energy of motion

potential energy – energy stored in an object due to its position

ratio – the relationship in quantity, amount, or size between two or more things

simple machine – any of various elementary devices considered as the elements of which all machines are composed and including the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw

weight – response of mass to the pull of gravity

work – product of a force applied to an object and the distance through which the force is applied; force times distance

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 1 of *The Case of the Powerful Pulleys*, read the program overview (p. 5) to the students. List and discuss questions and preconceptions that students may have about work, force, and energy.

2. Record a list of issues and questions that the students want answered in the program. Determine why it is important to define the problem before beginning. From this list, guide students to create a class or team list of three issues and four questions that will help them to better understand the problem. The following tools are available on the web site to assist in the process.

   Problem Board - Printable form to create student or class K-W-L chart

   Problem Based Learning (PBL) Questions - Questions for students to use while conducting research

   Problem Log - Printable log for students with the stages of the problem-solving process

   The Scientific Method - Chart that describes the scientific method process

3. Focus Questions - Questions at the beginning of each segment help students focus on a reason for viewing and can be printed ahead of time from the educator's area of the web site so students can copy them into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.

4. What's Up? Questions - Questions at the end of the segment help students predict what actions the tree house detectives should take next in the investigation process and how the information learned will affect the case. These questions can be printed from the web site ahead of time for students to copy into their science journals.

Careers

civil engineer
electrical engineer
chemist
construction worker
elevator operator
physicist

View Segment 1 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. Have students reflect on the "What's Up?" questions asked at the end of the segment.

2. Discuss the Focus Questions.

3. Students should work in groups or as a class to discuss and list what they know about work, force, and energy. Have the students brainstorm ideas on how to best get Jacob into the tree house. As a class, reach a consensus about what additional information they need to know before they can determine how to best lift Jacob into the tree house. Have the students conduct independent research or provide students with the information needed.

4. Have the students complete Action Plans, which can be printed from the web site, and then conduct independent or group research by using books and internet sites noted in the Research Rack section of the NASA SCI Files™ web site. Educators can also search for resources by topic, episode, and media type under the Educator's main menu option *Resources.*

5. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. The variety of activities is designed to enrich and enhance your curriculum. Activities may also be used to help students "solve" the problem along with the tree house detectives.

6. Have the students work individually, in pairs or in small groups, on the Problem-Based Learning (PBL) activity on the NASA SCI Files™ web site.

• To begin the PBL activity, read the scenario to the students.

• Read and discuss the various roles involved in the investigation.

• Print the criteria for the investigation and distribute.

• Have students use the Research Rack located on the web site and the online tools that are available.

7. Having students reflect in their journals what they have learned from this segment and from their own experimentation and research is one way to assess the students. In the beginning, students may have difficulty reflecting. To help students, give them specific questions to reflect upon that are related to the concepts.

8. Have students complete a Reflection Journal, which can found in the Problem-Solving Tool section of the online PBL investigation or in the Instructional Tools section of the Educator's area.

9. The NASA SCI Files™ web site provides educators with general and specific evaluation tools for cooperative learning, scientific investigation, and the problem-solving process.

Resources (additional resources located on web site)

Books

Cole, Joanna: *Magic School Bus "Plays Ball" -A Book About Forces.* Scholastic Inc., 1997, ISBN: 05909222408.

Dahl, Michael: *Inclined Planes.* Bridgestone Books, 1996, ISBN: 1560654473.

Dunn, Andrew: *Simple Slopes.* Thomas Learning, 1993, ISBN: 1568470177.

Hacker, Carlotta: *Scientists.* Crabtree Publishing Co., 1998, ISBN: 0778700062.

Lafferty, Peter: *Eyewitness Books: Force and Motion.* Darling Kindersley, 1999, ISBN: 0789448823.

Yount, Lisa: *Twentieth Century Women Scientists.* Facts on File, Inc., 1996, ISBN: 0816031738.

Web Sites

The Society of Women Engineers
Students and educators can visit the web site to learn more about engineering careers, scholarship programs, and more.
http://swe.org

Kinetic and Potential Energy
Visit this web site to learn why amusement parks are great places to study potential and kinetic energy.
http://library.thinkquest.org/2745/data/
ke.htm?tqskip1=1&tqtime=0710

Potential and Kinetic Energy
An interactive web site that explains the difference between potential and kinetic energy.
http://www.usoe.k12.ut.us/curr/science/sciber00/
8th/forces/sciber/potkin.htm

Energy: Grade 4
A fourth grade explanation of different types of energy.
http://www.nyu.edu/pages/mathmol/
textbook/energy.html

Gravity
Fourteen questions answered about gravity.
http://spaceprojects.arc.nasa.gov/Space_Projects/
SSBRP/gravity.html

Roadmaps & Rampways
Profiles of students with disabilities pursuing careers in mathematics, science, engineering, and technology. Heartwarming and inspiring stories.
http://www.entrypoint.org/rr/index.html

Activities and Worksheets

Inert Inertia

Purpose   To understand the basic concept of inertia
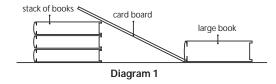
Background   Sir Isaac Newton was an English physicist and mathematician who studied the properties of force and motion. He developed three laws of motion known as Newton's Laws. Newton's First Law of Motion states that an object at rest will remain at rest, and an object in motion will remain in motion at a constant velocity unless an unbalanced force acts upon it. This tendency of objects to either remain at rest or in motion is called inertia.

Procedure

1. Stack two or three books on a flat surface and place one end of the board on top of the books to create a ramp so that one end is approximately 10 cm from the surface.
2. Measure the height of the ramp and record in data chart.
3. Use a thick book, like a dictionary, to form a wall at the bottom of the ramp. See diagram 1.
4. Place the large washer on top of the car.
5. Put the car at the top of the ramp and release it, making sure that you do not push the car.
6. After the car hits the wall, measure the distance from the car to where the washer landed and record this distance in the data chart.
7. Repeat steps 4-6 for two additional trials.
8. Raise the ramp an additional 5 cm and record height in data chart.
9. Repeat steps 4-7.
10. Repeat steps 8-9 by raising the ramp again.
11. Find the average distance (cm) that the washer traveled at each height.
12. Discuss your findings and conclusions.

stack of books   card board   large book

Diagram 1

Data Chart

	WASHER WILL TRAVEL			
Height of Ramp (cm)	Distance Trial 1 (cm)	Distance Trial 2 (cm)	Distance Trial 3 (cm)	Average Distance (cm)

Conclusion

1. Describe what happened to the washer when the car hit the wall.
2. Why do you think it happened?
3. Explain the relationship between the height of the ramp and the distance the washer traveled.
4. What is the relationship between inertia and the speed of the car at the bottom of the ramp?
5. Define inertia in your own words.
6. Explain how Jacob unfortunately encounters inertia on his scooter.
7. Using what you now know about inertia, explain why it is necessary to wear seat belts in a vehicle.

Extension

If the heights of the ramps were the same for all groups, have students share their data as a class and find a class average for each trial. Create a graph showing the relationship between the height of the ramp and the distance the washer traveled. Use washers of different weights and repeat experiment.

Forcing the Issue of Force

Purpose   To understand that force is needed to do work

Procedure
1. In your science journal, define work.
2. Discuss your definition with your group and reach a consensus.
3. Discuss lifting the weight, using an inclined plane, a pulley, and rope.
4. Predict which way of lifting the weight will require the most force and record in data chart.
5. Loop one end of the rope through the hook of the weight and tie a knot to secure the weight to the rope.
6. Loop the other end of the rope through the spring scale hook and secure with a knot. See diagram 1.
7. Hold the spring scale in one hand until the rope is taut and the weight is resting on the floor. The spring scale should read "0."
8. Have your partner hold the meter stick with one end on the floor next to the rope and weight. Slowly lift the weight 30 cm from the surface.
9. Read the spring scale and record the amount of force in data chart.
10. Place the weight at the bottom of the inclined plane and place the meter stick along the side of the inclined plane.
11. Holding the spring scale in one hand, slowly pull the weight 30 cm up the inclined plane.
12. Read the spring scale and record the force.
13. Untie the spring scale from the rope and loop the rope through the pulley.
14. Reattach the spring scale to the rope.
15. Hang the pulley from the hook designated by your teacher. See diagram 2.
16. Place the meter stick so that you can measure the distance to lift the weight.
17. Hold the spring scale in one hand and slowly pull down, lifting the weight 30 cm. Record the force.
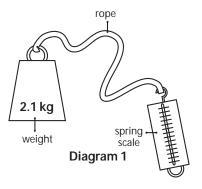18. Compare the amount of force needed for each test and discuss the results.

Conclusion
1. How did the force that was needed to lift the weight compare with the rope, the inclined plane, and the pulley?
2. Was your prediction correct? Why or why not?
3. Which simple machine do you think the tree house detectives should use to get Jacob into the tree house? Why?
4. Why do people use simple machines?
5. How can you use this information to help solve problems in your daily life?

Materials (per group)

1 pulley
hook setup for pulley
1 inclined plane (40 cm)
1 rope
1 2.1 kg weight with hook
1 spring scale
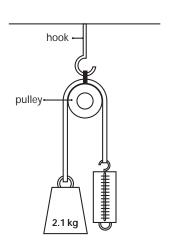meter stick
calculator (optional)
science journals

Diagram 1

Diagram 2

	Force	Distance
Rope Only		
Inclined Plane		
Pulley		

Stop in the Name of Energy!

Purpose

To understand the difference between kinetic and potential energy
To understand friction

Procedure

1. In your science journal, write definitions for potential energy, kinetic energy, and friction.
2. Discuss your definitions with your group and reach a consensus for each term.
3. Measure and cut five strips of waxed paper 30 cm x 4 cm.
4. Tape the top of each strip of waxed paper onto the cardboard, leaving space between each strip. Label each strip A, B, C, D, and E. See diagram 1.
5. Stack several books and place a large piece of waxed paper on the table in front of the books. This piece will be used for any drips that might occur.
6. Lean the cardboard against the stack so that the cardboard is slanted away from the books and the bottom edge is on the waxed paper. See diagram 2.
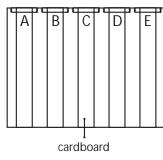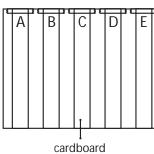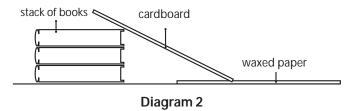

cardboard

Diagram 1

Materials

small amounts of
    vegetable oil,
    water, salt, and
    butter
2 small eyedroppers
waxed paper
cardboard (40 cm x
    30 cm)
5 checkers
tape
scissors
books
metric ruler
paper towel
science journal

stack of books   cardboard

waxed paper

Diagram 2

7. Strip A will be the control strip.
8. Using an eyedropper, place five drops of water on strip B.
9. On strip C, place five drops of water and then sprinkle a pinch of salt on top of the water.
10. Using a paper towel or napkin, smear a small amount of butter on strip D.
11. Using the other eyedropper, place five drops of vegetable oil on strip E.
12. Place a checker on the top of strip A. What type of energy does the checker have?
13. Let go of the checker and observe the distance that the checker moved down the waxed paper. What type of energy did the checker have as it moved?
14. Measure the distance and record in the data table below.
15. Repeat steps 11-13 for two more trials.
16. Repeat steps 11-14 for each additional strip.
17. Calculate the average distance each checker moved for each strip.
18. Discuss your findings and compare strips 2-5 to the first strip (control).
19. Discuss your definition of potential energy and kinetic energy and decide whether your definitions were correct.
20. Discuss friction and how it differed for each strip.

Stop in the Name of Energy!

Data Table

Strip	Trial 1	Trial 2	Trial 3	Average
A				
B				
C				
D				
E				

Questions

1. Describe how the checker received its potential energy. _____

_____

_____

_____

2. What happened as the checker moved down the strips? _____

_____

_____

3. Why did the checker move farther on some strips in relation to others? _____

_____

_____

4. Why do we strive to overcome friction? _____

_____

_____

5. How can you apply today's learning to another part of your life? _____

_____

_____

_____

_____

Extension

Use a penny as a weight for each checker. Predict whether the outcomes will be different. Repeat trials and compare. Continue to add more pennies to vary the weight and compare results.

Wait, Weight Doesn't Matter?

Purpose

To learn that gravity pulls all objects towards the center of the Earth
To learn that air resistance can change the speed in which objects will fall

Procedure

1. Take a coin and trace it onto the paper.
2. Cut out the circle, making sure that the paper circle is not bigger than the coin.
3. Predict what will happen if you drop the coin from one hand and the paper coin from the other. Record your prediction in your science journal.
4. Place the coin in one hand and the paper coin in the other. Drop them both at the same time. Record your results.
5. To further enforce the idea that all objects are going to drop at the same rate, try the next activity.
6. Stack 3 coins on top of each other and tape together.
7. Place one coin on the edge of the table and place the stack of coins on the edge also, but 5 cm apart from the single coin.
8. Place a ruler behind the coins so that the ruler is touching them.
9. Make a prediction as to what is going to happen when you push the ruler and make the coins fall off the table.
10. Using the ruler, push the coins off the table at the same time. Observe and record your observations in your science journal.
11. Discuss your results with your team partner and class.

Conclusion

1. When the coin and paper coin were dropped separately, what happened and why?
2. In the experiment with the single coin and stack of coins, what happened and why?
3. If gravity is always pulling you down, how does it help you?
4. How would life be different if we had less gravity or no gravity at all?
5. Would a bowling ball and a pebble fall at the same speed and hit the ground at the same time if dropped from a high building?
6. NASA astronauts on the Moon dropped a feather and a hammer. Which one do you think hit the moon surface first and why?

Extension

Research terminal velocity to find out more about how gravity affects objects as they fall.

Newton Has the Joules

Purpose: To calculate work in a variety of tasks

Formulas/conversions:
Work = Force x Distance (W = F x d)
lb = 2.21 kg
1 kg = 9.8 newtons
1 newton-meter = 1 joule

Materials

scales or balance
objects to lift
meter sticks
calculators
science journal

Background

Work is done by a force acting through a distance. For work to be done, a force must move an object. If there is not movement, there is no work. Work is the product of the force applied to an object and the distance through which the force is applied. The formula used to express this concept is work (W) = force (F) x distance (d). As you can see from the formula, two conditions must be met for work to be done. One, a force must be applied, and two, the force must make the object move. To calculate how much work is being done, follow these steps:

1. Find the mass of the object in grams and convert to kilograms.
2. Convert the mass of the object to weight by multiplying the mass by 9.8. Force is measured in newtons, so this number is the amount of force or the number of newtons that it will take to lift the object.
3. Measure (in meters) the distance that the object is lifted. Remember that the force must be applied in the same direction. If you lift an object 2 meters and walk 5 meters with it, you only did work when you lifted the object.
4. Multiply the number of newtons and the distance the object was lifted to get the unit of work, which is called a newton-meter (N-m).
5. One newton-meter is equal to one joule (unit of measure for energy or work).

Procedure

1. Your group will be competing with the other groups in your class. The object of the game is to do more work than any other group.
2. You have 10 minutes to carefully read the explanation above and discuss within your group how work is done. Reach a consensus about how to do more work than the other groups.
3. Choose one person in your group to be the worker.
4. Choose three objects in the classroom for the worker to lift and record them in your science journal.
5. Using the balance, find the mass of the first object and convert to newtons.
6. Have the worker lift the object. Measure and record the distance the object was lifted.
7. Multiply the newtons and the distance to find Newton-meter (unit of work).
8. Convert newton-meters to joules and record in your science journal.
9. Repeat steps 3-8 with the other two objects.
10. Find the sum of the three joules of work completed by your group.
11. Share with the class the amount of work your group did to determine which group did the most work. They are the "hardest workers."

Conclusion

1. What is force?
2. What is work?
3. Since Jacob weighs 90 lb and they need to lift him over 3.5 m, how much work will they need to do to lift him to the tree house?
4. What other factors do the tree house detectives have to consider to calculate the amount of work needed to get Jacob into the tree house?

Going Up Anyone?

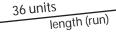**Problem**   To learn about ratios while developing a ramp

Background   A ratio is the quotient of two numbers or mathematical expressions. For example, the ratio of 6 to 3 may be expressed as 6:3, 6/3, and 2 to 1. A ratio is used to show a relationship in quantity, amount, or size between two or more things.

Procedure

1. Discuss ratios. In your science journal, list various ratios that you may have encountered in everyday life.
2. In Segment 1, Bianca suggested that the tree house detectives check out ramps as a possible solution to the problem. A handicap ramp must be built by using a ratio of 12 to 1 (12:1), which means that for 1 unit of height (rise) you need 12 units of length (run).

Materials

large piece of cardboard
books or bricks
tape measure or meter stick
pencil
scissors
science journal

36 units
length (run)
height (or rise)
3 units

3. Discuss in your group any ramps that you may have seen. If possible, walk around your school to look at any handicap ramps that may be found. Measure the rise versus the run and record in your science journal.
4. Using bricks or books, construct a platform 1 to 12 cm high that will be the platform for the top of your ramp.
5. Measure the actual height or rise of the platform in cm and record in your science journal.
6. Multiply the height by 12 to determine the length (run) of the ramp.
7. Using cardboard, measure and construct your ramp.
8. Share what you have constructed and explain the math you used to determine the length (run) of each ramp.
9. If you were able to measure the rise and run on any ramps on the school grounds, calculate to find whether they meet the 12:1 ratio.
10. Jacob will have to be lifted 3.5 m. Using a 12:1 ratio, how long will the ramp need to be?

Conclusion

1. Why is it important to have a ramp ratio of 12:1 for handicapped people?
2. How can you determine how much length you need for a ramp if you know the height?
3. How would you determine the height of a ramp if you were only given the length?
4. Is the length of the ramp needed to lift Jacob reasonable? Why or why not?
5. Do you think the tree house detectives are going to build a ramp?

Answer Key

Inert Inertia

1. The washer continues to move in a forward motion.
2. Both the toy car and the washer were put into motion because of the ramp (force of gravity). According to Newton's First Law, objects that are in motion stay in motion. However, the car was acted upon by another force, the book wall, and therefore stopped. The washer was also in motion and continued its motion because it was not attached to the car.
3-4. The higher the ramp, the faster the car would move and the farther the washer would travel after the car struck the wall.
5. Answers may vary.
6. Jacob's scooter stops when it hits the curb, but he continues to move and flies through the air.
7. Answer will vary.

Forcing the Force

1. The students should have discovered that the inclined plane required less force to lift the weight. The pulley only used one string and that is the same as lifting the weight without a pulley. If additional pulleys and strings are used then the force would reduce.
2. Answers will vary.
3. Answers will vary. Students will probably say the inclined plane because this experiment concluded that the inclined plane took less force to lift the weight.
4. Answers will vary but should include that simple machines make "work" easier.
5. Answers will vary.

Stop in the Name of Energy!

1. The checker received its potential energy from the person placing it at the top of each strip.
2. Answers will vary.
3. The amount of friction was stronger on some strips.
4. We strive to overcome friction so machines can become more efficient.
5. Answers will vary, but should include answers such as oil for engines, bike gears, driving on wet roads, and so on.

Wait, Weight Doesn't Matter?

1. The coin hit the floor before the paper coin. As the paper coin fell, air resistance opposed its downward motion, so it moved more slowly.
2. The single coin hit the floor at the same time as the stack of three coins. Even though the stack of coins was heavier, it did not hit the floor first because the single coin had enough weight to overcome the small amount of air resistance.
3. Gravity is the force that keeps you and other objects on the ground. If it weren't for gravity, we would have a difficult time staying in one place!
4. If there were less gravity, we would weigh less and be able to jump higher. Depending on how much gravity there was, we might even need to be weighted down so as not to float away. If there were not any gravity, we would float around like astronauts do in space.
5. Regardless of their masses, objects accelerate at the same rate. The acceleration of a falling object is due to the force of gravity between the object and the Earth. So if a pebble and a bowling ball were dropped at the same time from the same height, they would hit the ground at the same time.
6. When the astronauts dropped the feather and the hammer on the Moon, they proved that Galileo was correct in his description of the motion of falling objects. The feather and the hammer hit the surface of the Moon at the same time. They accelerated at the same speed, and because there is no air on the Moon, there was no air resistance to slow the feather down as on Earth.

Newton Has the Joules

1. Force is a push or a pull applied to an object.
2. Work is done when you apply a force to an object over a distance.
3. 1,396 joules. To find Jacob's mass, divide 90 pounds by 2.21 to get 40.7 kilograms. Multiply 40.7 kilograms by 9.8 newtons to get 398.9 newtons. Multiply 398.9 newtons by 3.5 meters to get 1,396 newton-meters. Convert newton-meters to joules.
4. The tree house detectives must also consider friction and the weight of the rope and any other materials used to lift Jacob up into the tree house.

Going Up Anyone?

1. Handicap ramps need a ratio of 12:1 to make it easier for people to walk or push a wheelchair up the ramp. If the ramp were too steep, it would be too difficult.
2. To determine the length of a ramp, multiply the height by 12.
3. To determine the height of a ramp, divide the length by 12.
4. Students should conclude that the ramp would need to be 42 meters long, much too long, since most yards are not that big.
5. Answers will vary, but most should determine that the tree house detectives will not build the ramp.

On the Web
Where DOES My Energy Come From?

1. The energy for all food webs begins with the Sun.
2. Energy is gathered into one organism and transferred to others as they are eaten.
3. To get energy to our body, we need to eat and drink.